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Public exposure to sensitive forensic topics on YouTube: an evaluation of most viewed videos on sexual abuse, suicide, and autopsy

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Public exposure to sensitive forensic topics on YouTube: an evaluation of most viewed videos on sexual abuse, suicide, and autopsy

Eurasian Clinical and Analytical Medicine Original Research

Sensitive forensic narratives on YouTube

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Abstract

Aim: The aim of this study is to assess and evaluate the content quality of the most widely viewed YouTube videos addressing sensitive forensic medicine topics with direct societal impact, such as sexual abuse, suicide, and autopsy.

Methods: Within the scope of the study, YouTube searches were conducted using the keywords "sexual abuse," "suicide," and "autopsy." The reliability of the retrieved videos was assessed using a modified 5-item DISCERN instrument, while overall information quality was evaluated using the Global Quality Scale (GQS). Based on the scores obtained from these instruments, the videos were classified into three categories: good/excellent, moderate, and low quality.

Results: Of the analyzed videos, 12.2% were classified as good/excellent quality, 28.6% as moderate quality, and 59.2% as low quality. Videos in the good/excellent quality group had significantly higher median DISCERN scores compared with those of moderate- and low-quality videos ($p<0.001$). In contrast, mean GQS and DISCERN scores demonstrated a strong and statistically significant positive correlation with each other ($p<0.001$, $r=0.866$). Additionally, total likes showed strong positive correlations with both total number of comments and total view counts ($p<0.001$, $r=0.811$ and $p<0.001$, $r=0.813$, respectively).

Conclusion: A considerable proportion of videos available on the YouTube platform contain inaccurate, misleading, or suboptimal-quality information. These findings highlight the variability in the quality and reliability of forensic-related content shared on digital platforms and underscore the need for improved dissemination and visibility of scientifically reliable/credible information.

Keywords

YouTube, sexual abuse, suicide, autopsy, primary care

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Introduction

The century in which we live is commonly referred to as the age of information technology. With the advent of this new era, uncertainty has progressively increased, and individuals have begun to seek information through a wide range of channels. Among these, digital platforms have emerged as one of the most prominent and influential sources of information.[1]

Advances in digital technology have substantially transformed access to health-related information, with digital platforms increasingly replacing traditional media sources. In this context, YouTube has emerged as a prominent video-based information platform, extending its influence beyond entertainment to sensitive domains such as health, forensic medicine, and psychology.[2,3]

Forensic medicine encompasses ethically complex and socially sensitive topics that concern society as a whole, such as sexual abuse, suicide, and autopsy.4 How content related to these subjects is represented on publicly accessible digital platforms such as YouTube, and how it is utilized by users, is of considerable importance from both academic and societal perspectives.

The effects of digital media content on society have been frequently addressed in the literature.[5,6] However, insufficient attention appears to have been paid to the potential risks arising from the unregulated presentation of such sensitive content. Moreover, to the best of our knowledge, there is limited research directly addressing the present research. Therefore, the aim of this study is to systematically examine the most widely viewed YouTube videos on sexual abuse, suicide, and autopsy as an electronic information source and to evaluate their content characteristics, ethical appropriateness, informational accuracy, and overall quality.

Materials and Methods

This study was designed as a descriptive and analytical investigation. Search keywords were determined based on a preliminary review of relevant YouTube videos and commonly used topic-related terms. The keywords "sexual abuse," "suicide," and "autopsy" were used for video searches on YouTube (www.youtube.com). The videos were screened on 11 December 2025 and ranked in descending order according to view counts. Following a review of previous studies in the literature, the number of videos to be evaluated was determined.[7] These studies reported that approximately 90% of the analyzed content was captured within the first 60 videos. Therefore, the first 60 videos for each keyword were included in the analysis.[8-10] Repetitive videos, videos in languages other than Turkish, forensic medicine–unrelated content, videos containing commercial advertisements, and videos exhibiting substantial content duplication were excluded based on predefined exclusion criteria.

Video quality was assessed using the Global Quality Scale (GQS), a widely used 5-point scoring system for evaluating digital media content. Videos scoring 4–5 points were classified as good/excellent, 3 points as moderate, and 1–2 points as low quality.[2,8-10] The scoring system applied in the present study is described below:

Videos were scored using the GQS, where scores of 1–2 indicate low-quality content with poor flow and predominantly inaccurate or misleading information, 3 indicates moderate quality with a mix of accurate and inaccurate content, and scores of 4–5 represent high to excellent quality, characterized by fluent presentation and largely or entirely accurate, evidence-based information.[11]

All videos included in the study were independently evaluated by two physicians experienced in commonly encountered forensic issues in primary care. Inter-rater agreement was assessed using the kappa coefficient (0.882). Cohen's kappa values between 0.81 and 1.00 were interpreted as almost perfect agreement.[12] In cases of disagreement during the evaluations, the videos were re-reviewed by a third expert physician, and a final consensus decision was reached to complete the assessment process.

The reliability of the videos was evaluated using the DISCERN instrument, originally developed by Charnock et al. and applied in its subsequently updated form. The original structure of the scale consists of 16 items, with the first eight items focusing on the reliability of information presentation and the following seven items addressing content quality. The final item provides a holistic assessment of the overall quality level of the video.[13]

Video reliability was evaluated based on clarity of presentation, use of valid and up-to-date scientific sources, objectivity of information, provision of additional references, and adequate discussion of uncertainty or controversial aspects.

These items were scored in a dichotomous manner as "yes" or "no," with a "yes" response assigned 1 point and a "no" response assigned 0 points. Accordingly, the total score obtainable from the scale ranges from 0 to 5, with higher scores indicating greater video reliability. Similar measurement approaches have been reported in the literature for studies assessing the reliability of video-based content.[13]

For all videos, the upload date, total duration, number of views, number of likes, and number of comments were recorded. View, comment, and like metrics were additionally calculated as daily averages and evaluated alongside the total values.

The sources of the videos were classified into six distinct categories: academic/university (1), physician (2), non-physician healthcare professionals (3), TV/journalists (investigators) (4), independent users (5), and lawyer/court staff (6).

As this study analyzed only openly accessible videos on the YouTube platform, no participant data were collected, and therefore, informed consent was not required.

Ethical Approval

This study did not require ethical approval according to the relevant guidelines.

Statistical Analysis

Statistical analyses were performed using the SPSS 22.0 software package. Descriptive analyses included frequency and percentage distributions, as well as minimum, maximum, and median values. Data distribution characteristics were examined using the Shapiro–Wilk test. The non-parametric Kruskal–Wallis test was employed to assess differences between groups. Post hoc tests were applied for subgroup analyses. Correlations between groups were evaluated using Pearson correlation analysis. Inter-rater agreement was determined using the kappa statistic. In all analyses, a p-value of <0.05 was considered statistically significant.

Reporting Guidelines

This study is reported in accordance with the STROBE guidelines.

Results

A total of 180 videos were initially reviewed; however, 82 videos were excluded from the analysis in accordance with the predefined exclusion criteria. Of the excluded videos, 67 were unrelated to the study topic, 13 were repetitive videos, and 2 contained advertising content. Within the subgroup of the 67 unrelated videos, 27 were identified as music (song) videos and 6 as news-related content. The remaining 34 videos belonged to social media/series/films/individual users. Following this screening process, a total of 98 videos were included in the final analysis.

The median duration of the videos included in the study was calculated as 476.5 seconds (min–max: 10–5,501). The median number of views was 337,777.5 (749–64,333,673), and the median number of comments was 277 (0–29,463). The descriptive characteristics of the videos are presented in detail in Figure 1.

According to the GQS assessment, the videos exhibited a heterogeneous distribution in terms of quality level; 12.2% (n = 12) were classified as high quality, 28.6% (n = 28) as moderate quality, and 59.2% (n = 58) as low quality. A kappa coefficient of 0.882 indicated a high level of inter-rater reliability, demonstrating the robustness of the measurement process.

In the analysis based on upload source, all videos produced by academics/universities (n = 6) were classified within the high-quality group. The majority of videos created by physicians and by lawyers/court staff were found to fall within the moderate-to-high quality categories (90.9%, n = 10; and 100%, n = 5, respectively). In contrast, a substantial proportion of videos uploaded by TV/journalists (investigative) and independent users were classified as low quality (86.5%, n = 32; and 93.7%, n = 15, respectively). These findings suggest that the quality of video content may vary significantly according to the source of upload. The distribution of GQS scores according to upload sources is presented in detail in Figure 2.

When GQS results were analyzed according to uploader categories, videos produced by academic/university sources, physicians, and lawyers/judicial personnel received significantly higher scores, indicating a statistically significant difference between groups ($p<0.001$). According to the modified DISCERN scale, videos uploaded by television journalists and independent users received lower scores, also demonstrating a statistically significant difference ($p<0.001$). With respect to daily likes, the academic/university and independent user

Table 1. DISCERN score, total views, total comments, and like counts by video quality.

Video source	GQSa Median (min-max)	Total viewsb Median (min-max)	Total commentsc Median (min-max)	Total liked Median (min-max)
Low quality (n = 58)	2 (1-3)	465.557 (4.317-35.001.171)	330.5 (0-29.463)	3.000 (0-256.000)
Physician	3(2-4)	4 (3-4)	447.908 (10.855-50000)	0.515 (0.072-14.755)
Moderate quality (n = 28)	3 (3-4)	335.395 (749-18.000.000)	288 (0-14.741)	1.600 (0-206.000)
Good/excellent (n = 12)	4 (4-4)	66.641 (8.836-64.333.673)	207 (2-28.757)	1000 (0-213.000)

*Kruskal-Wallis Test
ap < 0.001, bp = 0.163, cp = 0.536, dp = 0.597
Abbreviations: min = minimum; max = maximum; DS = The modified DISCERN scale.

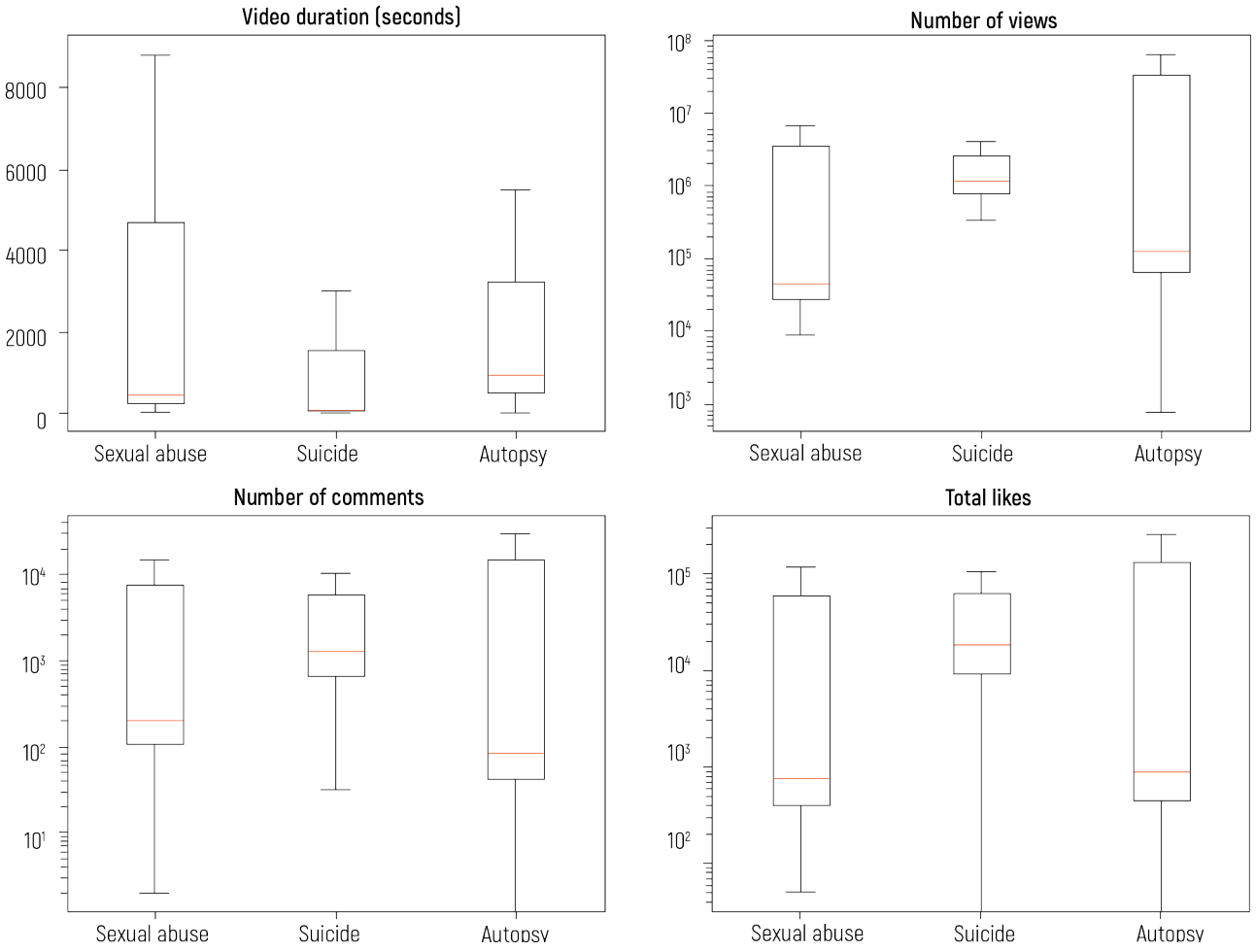
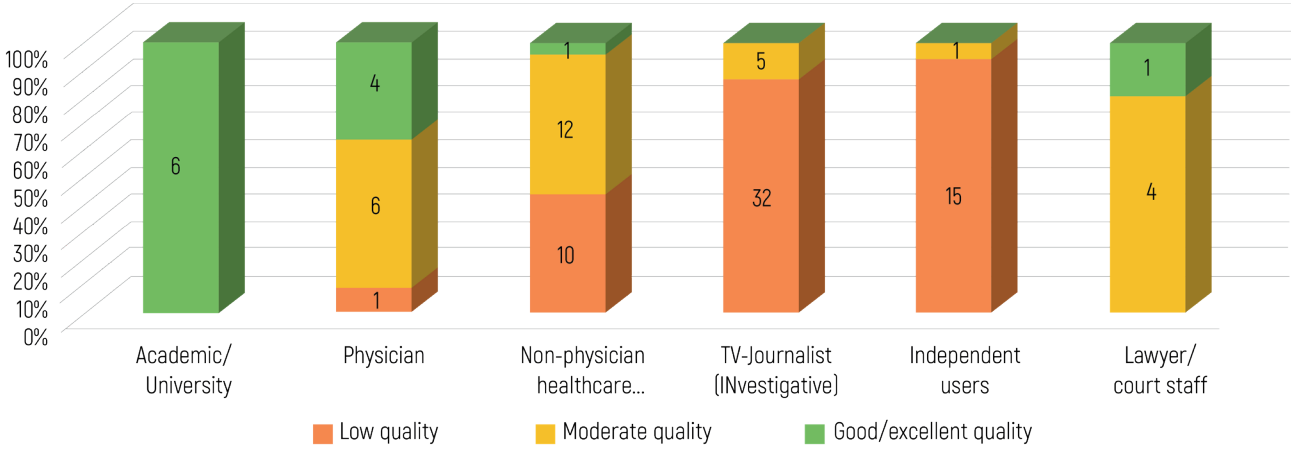


Figure 1. Distribution of video characteristics according to content category

*The central line represents the median, boxes indicate the interquartile range (IQR), and whiskers extend to the minimum and maximum values. Duration is presented on a linear scale, whereas engagement metrics (views, likes, and comments) are displayed on a logarithmic scale due to their highly skewed distributions.



Figür 2. Distribution of video quality across video sources

*A 100% stacked bar chart illustrates the proportional distribution of low, moderate, and good/excellent quality videos according to source categories. Percentages were calculated within each source. Overall differences were assessed using the chi-square test

groups showed higher values, with a statistically significant difference between groups (p=0.004). In contrast, no statistically significant differences were observed among uploader categories in terms of daily view rates or daily comment rates (p=0.089 and p = 0.170, respectively). The detailed data are provided in Supplementary Table 1.

As video quality increased, modified DISCERN scores also increased, with statistically significant differences observed between quality groups (p < 0.001). In contrast, no statistically significant differences were found among video quality categories in terms of daily view rates, daily comment rates, or total number of likes (p=0.163, p=0.536, and p=0.597, respectively). These findings are presented in Table 1.

Intergroup correlations between video popularity metrics (total number of views, likes, and comments) and GQS and DISCERN scale scores were examined. Accordingly, no correlation was identified between video popularity and GQS or DISCERN scores. In contrast, mean GQS and DISCERN scores demonstrated a strong and statistically significant positive correlation with each other (p < 0.001, r = 0.866). A strong and statistically significant positive correlation was also observed between total likes and both total number of comments and total number of views (p<0.001, r = 0.811; and p<0.001, r = 0.813, respectively). Additionally, the total number of comments and the total number of views were strongly and positively correlated (p<0.001, r = 0.848).

Discussion

The twenty-first century is characterized as a period in which digital technologies have become an integral part of daily life, and internet use has expanded on a global scale. Owing to its free accessibility and capacity to reach broad user audiences, YouTube ranks among the most widely used video-sharing platforms in the digital environment. Particularly during and after the pandemic period marked by the emergence of life-threatening diseases affecting populations worldwide, individuals have increasingly turned to digital media to meet their need for rapid and convenient access to information. In parallel with the rise in internet use during this period, it is anticipated that YouTube's role as a resource for accessing medical information has increased substantially.

The presence of medical content on the YouTube platform does not imply that all available videos are of high quality or provide reliable information. Alongside useful and scientifically grounded material, the platform simultaneously hosts videos of low quality or containing misleading information. The widespread availability of low-quality or misleading content may facilitate the dissemination of misinformation within society, adversely affecting health literacy and potentially increasing levels of anxiety and panic. Our findings are expected to provide guidance for clinicians, academic institutions, and content creators regarding the overall quality and reliability of widely viewed videos addressing sensitive forensic medicine topics.

The findings of our study revealed that a substantial proportion of videos addressing sexual abuse, suicide, and autopsy were of low quality. In contrast, the limited number of high-quality videos predominantly originated from academic/university sources and physicians. Videos produced by television journalists and independent users were found to be predominantly classified within the low-quality category.

According to the GQS assessment, 12.2% (n = 12) of the videos were classified as high quality, 28.6% (n = 28) as moderate quality, and 59.2% (n = 58) as low quality. Although the literature on this topic is limited, Nicholas et al. reported that only 16% of the videos analyzed in their study were categorized as high quality[14] Similarly, Villafañe et al. found that the vast majority of videos exhibited a low level of evidence.[15] In addition, a study conducted by Erdoğan et al. during the pandemic period revealed that more than half of the videos were of low or moderate quality.[16] The quality distribution observed in the present study is consistent with these previously reported findings and demonstrates that the majority of forensic medicine–related content on YouTube is of low to moderate quality. Taken together, the available evidence presents a consistent pattern indicating that high-quality, evidence-based videos are limited in number.

In the present study, high-quality videos were primarily produced by academics/universities and physicians, whereas low-quality content was predominantly generated by television journalists and independent users. Similarly, Bora et al. reported that universities constituted the main source of high-quality videos, while low-quality content was largely produced by independent users. However, in that study, television- and journalist-generated videos were reported to fall within the high-quality category, a finding that differs from the results of the present study.[17] Conversely, the identification of independent users as a source of low-quality videos in the study by Şahin et al. is consistent with our findings.

Overall, this study demonstrates that when YouTube is used as a source of medical information, the characteristics of the content creator represent a decisive factor in determining video quality. According to our findings, academic/university and physicians are among the principal sources of high-quality video content, while videos produced by lawyers/court staff generally fall within the moderate-to-high quality range. Nevertheless, although all videos uploaded by academic/university institutions in our study were classified as high quality, their

number was limited. This highlights the importance of encouraging and supporting academic institutions, physicians, and forensic professionals to produce and disseminate evidence-based, objective, and high-quality medical video content.

Another important issue addressed in this study is the quantitatively higher prevalence of misleading or low-quality videos and their corresponding potential to reach broader audiences. Although our findings do not directly confirm this assumption, studies in the literature have demonstrated that low-quality content may achieve greater visibility and higher view counts.[17,18] Moreover, in our study, the number of videos produced by non-physician healthcare personnel, TV/journalists, and independent users was greater than that produced by academic/university sources, physicians, and lawyer/court staff, indirectly supporting this interpretation.

Engagement metrics such as view counts, likes, and comments should be interpreted with caution and should not be considered indicators of informational quality. In our study, popularity measures did not demonstrate a consistent association with quality or reliability scores. These findings underscore the importance for users and healthcare professionals to prioritize source credibility and evidence-based content rather than engagement rates.

Limitations

This study has limitations. Although videos were independently evaluated by multiple physicians, some subjectivity was unavoidable. Limiting the sample to the top 60 videos based on view count may have led to an overrepresentation of popular content, potentially resulting in the underrepresentation of newer or less-viewed high-quality videos. The restriction to Turkish-language content and the limited sample size reduce generalizability, while algorithmic bias cannot be entirely excluded despite cleared search histories.

Conclusion

The data obtained indicate that a substantial proportion of YouTube content addressing socially sensitive topics such as sexual abuse, suicide, and autopsy lacks adequate quality and has low quality and low reliability scores, whereas the number of high-quality videos remains limited. When interpreted within the scope of our study, the findings indicate a limitation in the reliability of highly viewed Turkish-language YouTube videos addressing sensitive forensic medicine topics. In particular, they underscore the importance of increasing the availability of scientifically grounded, verifiable content produced by academic institutions and clinical experts in forensic medicine topics that attract substantial public attention and involve high societal sensitivity.

Declarations

Ethics Declarations

This study was conducted using publicly available data and did not involve human participants, patient records, or animal subjects. Therefore, formal ethical approval was not required according to institutional and national research guidelines. The authors adhered to ethical standards in the collection, analysis, and reporting of data. Nevertheless, the study was performed in accordance with general ethical principles and the Declaration of Helsinki.

Animal and Human Rights Statement

This study did not involve any human participants or animals. All analyzed materials consisted of publicly available YouTube videos. Therefore, no procedures requiring compliance with human or animal research ethical standards were conducted.

Informed Consent

Informed consent was not required for this study, as no human participants, patient data, or identifiable personal information were included. The analysis was based solely on publicly accessible content.

Data Availability

The datasets used and/or analyzed during the current study are not publicly available due to patient privacy reasons but are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Author Contributions (CRediT Taxonomy)

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Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content, including study design, data collection, analysis and interpretation, writing, and some of the main line, or all of the preparation and scientific review of the contents, and approval of the final version of the article.

Abbreviations

DISCERN: Quality criteria for consumer health information
DS: The modified DISCERN scale
GQS: Global quality scale
IQR: Interquartile range
SPSS: Statistical package for the social sciences
STROBE: Strengthening the reporting of observational studies in epidemiology

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Work conditions and quality of life of physicians in Türkiye with burnout, job and life satisfaction, and workplace violence

Eurasian Clinical and Analytical Medicine Original Research

Burnout, satisfaction, and violence in MDs

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Abstract

Aim: This study aims to comprehensively examine the relationship between workplace violence and physicians' burnout (emotional exhaustion, desensitization, and personal accomplishment), job satisfaction, and life satisfaction, considering sociodemographic characteristics and utilizing validated Turkish versions of the relevant scales, in order to better understand physicians' occupational and psychological well-being in Türkiye.

Methods: This cross-sectional survey study included 135 physicians working in Mardin, Türkiye. Data were collected using the Maslach Burnout Inventory (MBI), including the subscales of emotional exhaustion, desensitization, and personal accomplishment; a job satisfaction scale; a life satisfaction scale; and a workplace violence scale. All Turkish-adapted scales were administered using a 5-point Likert-type format. Data were analyzed using SPSS version 26.0.

Results: Our burnout subscales' Cronbach's à coefficients (internal consistency) were 0.949 for emotional exhaustion, 0.868 for desensitization, and 0.803 for personal accomplishment. The job satisfaction scale had 0.847 Cronbach's à, the life satisfaction scale 0.896, and the workplace violence scale 0.640.

Conclusion: The scales demonstrated generally acceptable internal consistency. Hospital administrations and healthcare management should prioritize reforms to reduce burnout, improve job and life satisfaction, and prevent workplace violence.

Keywords

physician, burnout scale, job satisfaction scale, life satisfaction scale, workplace violence scale

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Introduction

Burnout was first described by Freudenberger in 1974 and is characterized by diminished physical, mental, and emotional energy resulting from chronic occupational stress, particularly among healthcare professionals. According to Maslach and Jackson's model, burnout consists of three dimensions: emotional exhaustion, desensitization (depersonalization), and reduced personal accomplishment. Emotional exhaustion refers to the depletion of emotional resources; desensitization involves negative and distant attitudes toward patients; and reduced personal accomplishment reflects a decreased sense of professional competence and achievement.[1,2]

Life satisfaction is a key component of a meaningful and fulfilling life.[3] Job satisfaction, one of the most studied constructs in work psychology, shapes employee attitudes and organizational effectiveness.[4] There is a strong interaction between job and life satisfaction, as satisfaction at work directly influences overall quality of life; therefore, modern organizations develop policies to enhance job satisfaction in order to improve overall well-being.[5]

Hospital workplace violence is defined as instances in which medical staff members are the targets of physical attacks, threats, or verbal abuse, all of which have a detrimental effect on their health, safety, and general well-being. Especially in Asia and North America, hospital-related workplace violence has become quite common.[6,7]

Although workplace violence, burnout, job satisfaction, work atmosphere, and perceived stress have been widely studied, their interrelationships remain unclear. Therefore, this study aimed to examine these associations using validated Turkish versions of established scales among physicians working in Mardin, Türkiye.

Materials and Methods

Participants

This study was conducted between January 2024 and June 2025 using online and face-to-face data collection methods. This cross-sectional study included a total of 135 physicians working in various healthcare institutions in Mardin province, Türkiye. In Figure 1, the location of Mardin province is shown. The survey was conducted in three sections: Sociodemographic characteristics (13 questions), general information (10 questions), and scales: 1 = Maslach Burnout Inventory, (MBI) emotional exhaustion 9 items, desensitization 5 items, personal accomplishment 8 items; 2 = Job Satisfaction Scale 5 items; 3 = Life Satisfaction Scale 5 items Dağlı and Baysal and the Workplace Violence Scale were applied as 3 items.1,3,8-10 Validated Turkish versions of all scales were used, and all items were rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Ethical Approval

The study was approved by the Ethics Committee of Mardin Artuklu University Non-Interventional Clinical Research Ethics Committee (Date: 05.03.2024, Decision No: 2024/3-34).

Figure 1. Visual representation of Mardin provinceby video quality

Statistical Analysis

Data were analyzed using SPSS 26.0. Normality was assessed by skewness and kurtosis (−1 to +1 accepted as normal). Independent t-test and ANOVA were used for group comparisons. Descriptive statistics were expressed as frequency, percentage, mean, and standard deviation. A p-value<0.05 was considered statistically significant.

Reporting Guidelines

The study was reported in accordance with the STROBE guidelines.

Results

Of the 135 physicians, 33.3% were female and 66.7% male, with a mean age of 36.74 ± 7.49 years. Most were married (57%), and half were specialists (50.4%). Professional experience was distributed across all categories, with 31.9% having 1–5 years and 20.7% more than 15 years of experience. Approximately one-third had worked in Mardin for more than five years (32.6%). Significant associations were found between age and personal accomplishment, title and desensitization, and salary and emotional exhaustion (p<0.05), whereas no other sociodemographic variables were significantly related to the burnout scale (p>0.05) (Supplementary Table 1).

General life characteristics are presented in detailed data, which is provided in Supplementary Table 2. While 83.7% of physicians chose their profession voluntarily, only 50% would choose medicine again. The rate of planning to go abroad was 38.8%. Regarding health and lifestyle, 25.2% reported having a disease, 25.9% used medication regularly, 9.6% used antidepressants, 27.4% smoked, 14.8% engaged in regular artistic activities, and 35.6% exercised regularly. Additionally, 52.6% would recommend working in Mardin, 74.8% owned a car, 53.3% owned a house, 57.8% had loan debt, and 84.8% worked in the public sector.

MBI was translated into Turkish and adapted for physicians under three subdimensions (emotional exhaustion, desensitization, and personal accomplishment). As shown in the detailed data provided in Supplementary Table 3, emotional exhaustion included nine items, including the question "I feel exhausted when I finish the day at the hospital/workplace," with a Cronbach à value of 0.949, indicating high internal consistency. The personal accomplishment subscale consisted of eight items, with the highest mean score observed for the question "I have accomplished many significant things in medicine" and a Cronbach à value of 0.803. The desensitization subscale included five items, among which the question "I really don't care what happens to some patients" received a high score, with a Cronbach à value of 0.868.

Job Satisfaction Scale mean scores ranged from 2.67 to 3.30 across five items, with high internal consistency (Cronbach à = 0.847). The highest score was for "I do my job with passion" (3.30 ± 1.12), followed by "I find my job unappealing" (2.88 ± 1.23) (The negatively worded item ("I find my job unappealing") was reverse-coded during analysis), "Time is going well at work" (2.74 ± 1.01), and "I am very satisfied with my current job" (2.68 ± 1.14). The lowest score was observed for "I find happiness in my work" (2.67 ± 1.18).

Life Satisfaction Scale mean scores ranged from 1.04 to 2.87, with the highest score for "I'm satisfied with my life" (2.87 ± 1.13), followed by "My living conditions meet my ideals in many ways" (2.46 ± 1.11) and "I have everything I want in my life" (2.41 ± 1.21). Lower scores were observed for "If I could live it again, I wouldn't change a thing" (2.07 ± 1.14), and the lowest for "My living conditions are perfect" (1.04 ± 1.12). Internal consistency was high (Cronbach's à = 0.896).

Workplace Violence Scale mean scores ranged from 2.27 to 3.56, with verbal abuse highest (3.56 ± 1.35), followed by psychological violence (3.36 ± 1.38), and physical violence lowest (2.27 ± 1.28). Internal consistency was moderate (Cronbach's à = 0.640).

Correlation analyses showed weak but significant positive associations

between emotional exhaustion and verbal violence (r = 0.273, p=0.01) and psychological violence (r = 0.288, p=0.001), with no significant link to physical violence (Figure 2). Personal accomplishment was not associated with any type of violence. Desensitization was also not significantly related to violence, although psychological violence showed a borderline association (r = 0.166, p=0.055).

Heatmap showing Pearson correlation coefficients (r) between types of violence (verbal, physical, psychological) and burnout subdimensions (emotional exhaustion, personal accomplishment, desensitization). Values inside the cells represent correlation coefficients. Statistically significant correlations are indicated with an asterisk (*p<0.05).

Discussion

In this study of 135 physicians (66.7% male; mean age 36.74 ± 7.49 years), burnout did not differ by gender, marital status, professional experience, or years working in Mardin. Personal accomplishment was higher

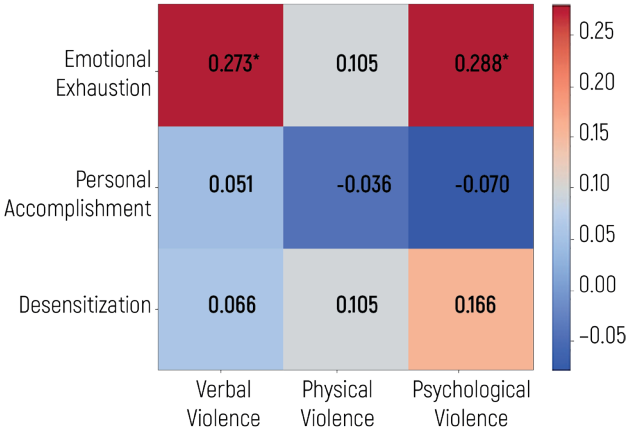

Figure 2. Correlation between types of workplace violence and burnout subdimensions among healthcare workers

among physicians over 50, while desensitization was more pronounced among general practitioners. Education level was associated with desensitization and personal accomplishment, and lower income was linked to higher emotional exhaustion. These findings indicate that age, professional position, and income may influence burnout dimensions. Although most participants chose medicine voluntarily, nearly half would not choose the profession again, suggesting ambivalence about long-term professional satisfaction.

Mean scores indicated high emotional exhaustion and desensitization among physicians. Similar findings in Türkiye report increased burnout in high-shift units and in the presence of workplace violence.[11,12] Although gender has been identified as an important factor in some studies,[13] no significant association was found in our sample. Evidence from China suggests that reducing workplace violence and improving working conditions decreases burnout.[14] These results underscore the need to enhance working conditions and psychosocial support to mitigate physician burnout.

The Job Satisfaction Scale demonstrated high reliability, with findings indicating a moderate level of job satisfaction. The highest mean score was observed for "I do my job with pleasure," whereas overall satisfaction items were lower. These results are consistent with previous studies supporting the validity and reliability of the Turkish short form of the scale.[10,15] Mobbing has also been identified as a significant factor associated with reduced job satisfaction.[16,17] Life satisfaction levels were generally low. Although "I am satisfied with my life" received the highest score, particularly low ratings for "My living conditions are perfect" may reflect the challenging socio-economic conditions in Mardin. This finding aligns with studies reporting decreased life satisfaction among healthcare workers exposed to mobbing.[17] Moreover, managerial and institutional interventions have been emphasized as necessary to improve job satisfaction in healthcare settings.[18] Consistent with Keser's findings, job satisfaction was higher than life satisfaction in this study.[5] Physicians reported the highest exposure to verbal violence, followed by psychological violence, with physical violence being the least frequent. These findings suggest greater exposure to non-physical forms of violence. The scale showed moderate internal consistency, and frequent verbal and psychological violence may adversely affect burnout, job satisfaction, and mental health.

These findings are consistent with the literature. A study in Sivas reported that 58% of physicians experienced violence, predominantly psychological/verbal.[19] Studies from China emphasized the widespread nature of verbal violence and insufficient institutional support.[20-23] Similarly, research in Istanbul showed that exposure to violence was associated with higher emotional exhaustion, increased suicidal ideation, and lower job satisfaction.[24]

Significant positive correlations were found between verbal and psychological violence and emotional exhaustion, whereas physical violence was not associated. A borderline relationship was observed between psychological violence and desensitization, and no association was found with personal accomplishment. These findings align with the literature, indicating that verbal and psychological violence contribute to burnout and may negatively affect job motivation and organizational commitment.[17,21,24]

Limitations

The relatively small sample size, single-center design, and cross-sectional nature of the study limit the generalizability of the findings and preclude causal interpretations. In addition, the use of self-report measures may introduce response bias.

Conclusion

This study evaluated burnout, job satisfaction, life satisfaction, and exposure to workplace violence among physicians, focusing on the relationship between workplace violence and burnout. Although physicians reported enjoying their work, overall job satisfaction was moderate, and life satisfaction was low, particularly regarding perceived living conditions. Verbal and psychological violence were the most common forms of exposure and were significantly associated with emotional exhaustion. These findings underscore the need for system-level strategies to address workplace violence in healthcare settings.

The Cronbach α values of the burnout, job satisfaction, and life satisfaction scales used in the study were found to be above 0.80; this indicates that the Turkish versions of the scales are reliable and applicable. The Cronbach's α value of the workplace violence scale was 0.640, indicating moderate internal consistency.

Declarations

Ethics Declarations

This study was approved by the Ethics Committee of Mardin Artuklu University Non-Interventional Clinical Research Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent

Informed consent was obtained from all participants prior to participation in the study.

Data Availability
The datasets used and/or analyzed during the current study are not publicly available due to patient privacy reasons but are available from the corresponding author on reasonable request.

Conflict of Interest
The authors declare that there is no conflict of interest.

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Conceptualization: M.C.Y.
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Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content, including study design, data collection, analysis and interpretation, writing, and some of the main line, or all of the preparation and scientific review of the contents, and approval of the final version of the article.

Abbreviations
ANOVA: Analysis of variance
MBI: Maslach Burnout Inventory
MDs: Medical doctors
SD: Standard deviation
SPSS: Statistical package for the social sciences
STROBE: Strengthening the reporting of observational studies in epidemiology

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Is the barrier concept in surgical gloves mechanical or antimicrobial? A survey of operating room nurses

Eurasian Clinical and Analytical Medicine Original Research

Barrier concept in surgical gloves

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Abstract

Aim: Surgical gloves provide a critical protective interface between patients and healthcare workers during invasive procedures. However, with the introduction of antimicrobial technologies, the concept of "barrier" may no longer be perceived solely as mechanical protection. This study aimed to evaluate operating room nurses' understanding of the barrier concept in surgical gloves and to assess whether conceptual confusion exists between mechanical and antimicrobial protection.

Methods: This cross-sectional, descriptive, anonymous online survey included 110 operating room nurses. Data were collected using a structured questionnaire evaluating demographic characteristics, perceptions of glove technologies, and clinical practice preferences. Group comparisons were performed using the Mann–Whitney U test, and correlations were analyzed using Spearman's correlation coefficient. This study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.

Results: Among participants, 65.5% defined the barrier concept as physical/mechanical resistance, whereas 34.5% defined it as antimicrobial/biological protection. In addition, 46.4% incorrectly identified the primary function of antimicrobial gloves as providing a thicker physical layer against perforation. Furthermore, 32.7% believed that orthopedic gloves contain antibiotics. In cases involving known infectious diseases, 48.2% preferred double standard gloving, while a considerable proportion reported glove combinations or layering preferences inconsistent with the intended mechanism of glove technologies.

Conclusion: There is notable conceptual confusion among operating room nurses regarding surgical glove technologies. Misinterpreting antimicrobial protection as mechanical reinforcement may create a false sense of security and compromise appropriate glove selection and layering. Regular in-service training on glove mechanisms and layering strategies is needed.

Keywords

surgical gloves, anti-infective agents, local, cross-infection, nurses, operating rooms

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Introduction

Surgical gloves are among the fundamental personal protective equipment used during invasive procedures and provide a physical barrier between patients and healthcare workers to reduce transmission of infectious agents through blood and body fluids. However, glove perforations occur frequently during operations and often remain unnoticed. The incidence of glove microperforation increases with duration of use and is more pronounced during prolonged procedures.[1]

In orthopedic and trauma surgery, glove perforation rates are higher due to mechanical stress and sharp instruments, with rates ranging from 10% to 50%, most going unrecognized.[2-4] Loss of glove integrity is a potential risk factor for surgical site infection.[3]

Advances in glove technology have expanded the range of available products beyond conventional mechanical protection. Surgical gloves now differ with respect to material composition, thickness, and additional features such as antimicrobial coatings and perforation indicator systems.[4] This diversity has introduced ambiguity in both clinical terminology and practical understanding of the term "barrier."

Traditionally, the barrier concept referred to mechanical protection through glove thickness. More recently, antimicrobial agents have introduced the concept of a biological barrier to reduce pathogen load after glove breach.[5] However, limited data exist on how healthcare professionals interpret these technologies in practice.

Although glove perforation rates and antimicrobial coating effects have been widely investigated, studies examining how nurses conceptualize the barrier concept remain scarce. Inadequate differentiation may contribute to inappropriate glove selection and a misleading perception of protection.

Accordingly, this study aimed to evaluate operating room nurses' knowledge of current glove technologies and to examine how their interpretation of the barrier concept may influence clinical practice.

Materials and Methods

Study Design and Participants

This study was designed as an anonymous, cross-sectional, descriptive online survey evaluating operating room nurses' perceptions of surgical glove technologies and the possible impact of these perceptions on safety-related clinical practices. The target population consisted of nurses actively working in operating rooms in public and private hospitals in Türkiye. Participation was voluntary, and no personally identifiable data, including names, identification numbers, IP addresses, or institutional affiliations, were collected. Participants were recruited using voluntary response sampling through digital platforms.

The inclusion criteria were as follows:

- at least 3 months of operating room experience,
- active participation in surgical procedures,
- voluntary agreement to participate.

The exclusion criteria were as follows:

- working outside the operating room setting,
- incomplete or inconsistent survey responses.

Data Collection

Data were collected using a structured questionnaire developed by the researchers after review of the relevant literature. The survey was administered digitally using Google Forms.

The questionnaire consisted of three main sections.

Demographic and Professional Characteristics

Participants were asked about age, sex, years of professional experience, and the average number of surgeries attended per month.

Conceptual Definition and Knowledge Level

Questions covered:[1] definition of "barrier glove" (mechanical vs. antimicrobial);[2] primary mechanism of antimicrobial gloves; (3) differences between orthopedic and standard gloves;[4] preferred glove strategy for infectious cases;[5] reasons for preferring orthopedic gloves; and[6] first action after glove perforation.

Practice Preferences and Perception Assessment

Participants' perceptions were evaluated using a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree) for the following statements:

- Antimicrobial gloves are more resistant to perforation.
- Thicker gloves reduce infection transmission risk.
- The barrier concept primarily refers to mechanical durability.
- Antimicrobial gloves alone are sufficient in high-risk cases.

Ethical Approval

This study did not require ethical approval according to the relevant guidelines.

Statistical Analysis

Statistical analyses were performed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequency and percentage. Comparisons between groups according to barrier definition were performed using the Mann–Whitney U test. The relationship between years of professional experience and knowledge score was assessed using Spearman's correlation coefficient. A p-value of less than 0.05 was considered statistically significant.

Reporting Guidelines

This study is reported in accordance with the STROBE guidelines.

Results

A total of 110 operating room nurses were included in the analysis. Participants' demographic characteristics, perceptions of glove technologies, and clinical practice preferences were evaluated.

Demographic Characteristics

The mean age of participants was 32.8 ± 6.4 years, and the mean duration of professional experience was 7.9 ± 4.8 years. Among the participants, 58.2% reported participating in 40 or more surgeries per month.

Most respondents were female (78.2%, n=86). Professional experience was relatively evenly distributed across categories: less than 5 years, 34.5%; 5–10 years, 37.3%; and more than 10 years, 28.2% (Table 1).

Table 1. Demographic characteristics of participants (n = 110)

Variable	n	%
Sex		
Female	86	78.2
Male	24	21.8
Professional experience		
<5 years	38	34.5
5–10 years	41	37.3
>10 years	31	28.2

Conceptual Definition and Knowledge Level

A total of 65.5% of participants defined the barrier concept as purely mechanical or physical resistance, whereas 34.5% associated it with antimicrobial or biological protection. Regarding the primary mechanism of antimicrobial gloves, 57.3% correctly identified pathogen-load reduction after perforation as the principal mechanism. However, 46.4% incorrectly believed that antimicrobial gloves mainly function by providing a thicker physical layer.

Concerning orthopedic gloves, 71.8% correctly identified increased thickness as the main distinguishing feature. Nevertheless, 32.7% incorrectly believed that orthopedic gloves contain antibiotics.

In cases involving known infectious diseases, the most frequently

preferred strategy was double standard gloving (48.2%), followed by orthopedic plus standard gloving (17.3%). The detailed data are provided in Supplementary Table 1.

Clinical Practice Preferences

In cases involving known infectious risk, 48.2% of participants preferred double standard gloves, consistent with commonly recommended practice. However, alternative glove combinations were also reported, including antimicrobial plus standard gloves (12.7%) and antimicrobial plus orthopedic gloves (6.4%). In addition, 4.5% stated that the glove layering sequence does not influence protection. The detailed data are provided in Supplementary Table 1.

Table 2. Glove combination preferences in high-risk cases

Preferred method	n	%
Double standard gloves	53	48.2
Orthopedic + standard	19	17.3
Antimicrobial + standard	14	12.7
Single standard glove	12	10.9
Antimicrobial + orthopedic	7	6.4
Layer sequence not important	5	4.5

Safety Perception and Likert Analysis

Participants' perceptions regarding glove technologies were assessed using a 5-point Likert scale. The belief that antimicrobial gloves are more resistant to perforation had a mean score of 3.28 ± 1.09. The statement "Thicker gloves reduce infection transmission risk" had a mean score of 3.74 ± 0.96. The statement "The barrier concept primarily refers to mechanical durability" had a mean score of 3.41 ± 1.02. Agreement with the statement "Antimicrobial gloves alone are sufficient in high-risk cases" was relatively low (2.36 ± 1.04) (Table 3).

Table 3. Attitudes and beliefs regarding glove technologies

Statement	Mean	SD
Antimicrobial gloves are more resistant to perforation	3.28	1.09
Thicker gloves reduce infection transmission risk	3.74	0.96
Barrier concept primarily refers to mechanical durability	3.41	1.02
Antimicrobial gloves alone are sufficient in high-risk cases	2.36	1.04

Group Comparisons

Comparison of Likert scores between barrier-definition groups using the Mann–Whitney U test showed that participants who defined the barrier concept as biological protection had significantly higher belief scores regarding the mechanical durability of antimicrobial gloves than those who defined it as mechanical resistance (mean 3.87 vs. 2.96, p=0.001). No significant correlation was found between years of professional experience and knowledge score (p=0.47).

Discussion

This study showed that operating room nurses' perceptions reflect not only a knowledge gap but also conceptual confusion that may influence safety practices. Notably, 46.4% of participants incorrectly identified the main mechanism of antimicrobial gloves as providing a thicker physical layer.

The barrier concept encompasses two distinct domains: mechanical and biological protection. In our study, 65.5% of participants defined barrier solely as mechanical resistance, suggesting antimicrobial technologies may be incorrectly perceived as mechanical reinforcement. This misperception may create a false sense of security, reducing vigilance during high-risk procedures.[6]

The principal mechanism of antimicrobial gloves involves activation of an internal agent (commonly chlorhexidine gluconate) after perforation, reducing microbial load at the breach site.[5,7] These gloves are intended for use as the inner layer in double-gloving systems. However, many participants reported using them as the outer layer, indicating an incomplete understanding of their mechanism and diminished practical benefit from incorrect application.

Orthopedic gloves provide enhanced mechanical resistance through increased thickness.[2] Nevertheless, nearly one-third of participants believed they contained antibiotics, suggesting biologically and mechanically enhanced gloves may be cognitively merged into a single protective category.

In cases involving hepatitis B virus (HBV), hepatitis C virus (HCV), or human immunodeficiency virus (HIV) risk, nearly half of participants preferred double standard gloves, compatible with current safety recommendations.[8,9] However, variability in glove selection suggests gaps in institutional education. The lack of correlation between experience and knowledge indicates this confusion is systemic rather than experience-dependent.

Another important issue is the dual use of the term barrier in the literature, referring to either mechanical durability or antimicrobial functionality. When terminology and educational content do not clearly distinguish these concepts, blended interpretations may develop among healthcare workers.

Taken together, these findings suggest that the barrier concept encompasses two mechanisms: preservation of glove integrity (mechanical barrier) and reduction of microbial load (antimicrobial barrier). Failure to distinguish these mechanisms may have implications for education, glove selection, and occupational safety.

Limitations

This study has several limitations. First, its cross-sectional design limits causal interpretation. Second, data were collected through self-report, which may introduce response bias. Third, the survey was conducted online using voluntary participation, which may have resulted in selection bias. Fourth, the questionnaire was developed by the researchers and was not based on a previously validated measurement tool. Finally, the study evaluated conceptual perceptions and reported preferences rather than directly observed clinical behavior.

Conclusion

This study demonstrates that operating room nurses have heterogeneous perceptions of surgical glove technologies and that the distinction between mechanical and antimicrobial aspects of the barrier concept is not consistently understood.

A considerable proportion of participants equated antimicrobial functionality with increased mechanical durability and showed limited awareness regarding appropriate glove layering in double-gloving systems. Misinterpretation of the barrier concept may indirectly affect surgical safety culture by creating a misleading sense of protection, particularly in high-risk settings.

Structured in-service education on glove technologies, institutional algorithms for glove selection and layering, and clearer distinction between antimicrobial and mechanical glove functions in clinical guidelines may help reduce this conceptual confusion. Surgical safety depends not only on the availability of protective equipment but also on an accurate understanding of how that equipment works.

Declarations

Ethics Declarations

This study did not require ethical approval in accordance with national regulations. The study was conducted in accordance with ethical standards.

Animal and Human Rights Statement
All procedures performed in this study were in accordance with the ethical standards of the national research framework and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent
Participation was voluntary and anonymous. Completion of the online questionnaire was accepted as implied consent.

Data Availability
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest
The authors declare that there is no conflict of interest.

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Author Contributions (CRediT Taxonomy)
Conceptualization: S.K.
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Investigation: S.K.
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Writing – Original Draft Preparation: S.K.
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Scientific Responsibility Statement
The authors declare that they are responsible for the scientific content of the article, including study design, data collection, analysis and interpretation, writing, critical scientific review of the content, and approval of the final version of the manuscript.

AI Usage Disclosure
Artificial intelligence was used only for language editing, wording support, and formatting assistance during manuscript preparation. It was not used for data generation, data analysis, or interpretation of the study findings. The authors reviewed and approved the final content.

Abbreviations
HBV: Hepatitis B virus
HCV: Hepatitis C virus
HIV: Human immunodeficiency virus
SD: Standard deviation
STROBE: Strengthening the reporting of observational studies in epidemiology

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National prevalence of potential nirmatrelvir/ritonavir drug interactions in U.S. adults: implications for safe antiviral prescribing

Eurasian Clinical and Analytical Medicine Original Research

National burden of Paxlovid drug-drug interactions

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Abstract

Aim: Nirmatrelvir/ritonavir is an oral antiviral for high-risk outpatients with COVID-19, yet ritonavir-mediated drug-drug interactions can preclude use or require mitigation, delaying time-sensitive therapy. We estimated the national prevalence of significant Paxlovid drug-drug interactions in U.S. adults.

Methods: We conducted a cross-sectional analysis of National Health and Nutrition Examination Survey (NHANES) 2017-March 2020 pre-pandemic data. Prescription medications were mapped at the ingredient level to the Food and Drug Administration (FDA) Paxlovid Fact Sheet interaction table and classified as Tier 1 (contraindicated) or Tier 2 (avoid/temporary holding, dose adjustment, or monitoring). Using NHANES complex survey methods, we estimated weighted prevalence and 95% confidence intervals (CI) for exposure. A sensitivity analysis was restricted to interviewer-observed medications (prescription medication seen variable [RXQSEEN] = 1). Polypharmacy was defined as ≥5 prescription medications.

Results: Among 9,693 adults, the weighted prevalence of exposure to any Tier 1 contraindicated medication was 6.88% (95% CI, 5.63-8.13), Tier 2 exposure was 27.74% (95% CI, 26.04-29.44), and any Tier 1 or Tier 2 exposure was 31.19% (95% CI, 29.15-33.22). In the RXQSEEN-restricted sensitivity analysis, prevalence estimates were 6.08% (Tier 1), 24.86% (Tier 2), and 28.05% (any Tier 1 or Tier 2). Among adults with polypharmacy, prevalence was 22.36% (Tier 1), 79.54% (Tier 2), and 86.50% (any Tier 1 or Tier 2). Simvastatin was the most common Tier 1 ingredient (4.27%).

Conclusion: Potential clinically significant Paxlovid drug-drug interactions are common in U.S. adults and highly prevalent among those with polypharmacy, underscoring the central role of clinical pharmacy in rapid medication reconciliation, interaction mitigation, and timely access to COVID-19 therapeutics.

Keywords

COVID-19, drug interactions, ritonavir, polypharmacy, medication reconciliation

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Introduction

Ritonavir-boosted nirmatrelvir (nirmatrelvir/ritonavir; Paxlovid) is a preferred oral antiviral for nonhospitalized patients at high risk for progression to severe coronavirus disease 2019 (COVID-19). Randomized trial evidence and large real-world studies demonstrate clinically meaningful reductions in hospitalization and death when treatment is initiated early in the disease course.[1-6] However, translating this efficacy into routine care depends on rapid, point-of-care therapeutic decision-making within a narrow treatment window, in which medication reconciliation and interaction screening often determine whether patients can access Paxlovid promptly or require an alternative regimen.[1-6]

A key limitation to widespread, guideline-concordant use is the drug-drug interaction (DDI) profile conferred by ritonavir, a potent inhibitor of cytochrome P450 3a (CYP3A) and P-glycoprotein. Depending on the concomitant medication, coadministration may be contraindicated or may require structured mitigation (e.g., temporary withholding, dose adjustment, enhanced monitoring) or selection of an alternate antiviral regimen.[7-9] These operational steps can delay treatment initiation and increase reliance on pharmacy support, particularly in settings with limited infrastructure for rapid interaction management.[7-10]

DDI burden is expected to be highest in older adults and those with polypharmacy, groups that also carry disproportionate risk for severe COVID-19 and are therefore most likely to meet indications for outpatient antiviral treatment.[9-12] Nationally representative estimates of potential DDIs can inform the scale of medication-reconciliation and pharmacist resources required for safe outpatient implementation, and can guide targeted decision support for the most common contraindicated agents.[11,12] Prior National Health and Nutrition Examination Survey (NHANES) based work has quantified the prevalence of potential DDIs with ritonavir-containing COVID-19 therapy in the U.S. population, underscoring DDIs as a common and clinically relevant barrier to outpatient antiviral prescribing at scale.[11] In parallel, expert guidance has emphasized that Paxlovid prescribing requires systematic recognition and management of interactions driven by potent CYP3A and transporter inhibition, with a practical distinction between agents that are contraindicated versus those that may be used with temporary holding, dose adjustment, or close monitoring.[9,10]

While this prior NHANES-based work represented an important first national estimate, that analysis was restricted to the cytochrome p450 3a4 (CYP3A4) metabolic pathway alone and applied a generic ritonavir interaction framework rather than Paxlovid-specific regulatory guidance.[11] Critically, it did not distinguish between agents that are contraindicated with nirmatrelvir/ritonavir, requiring a switch to an alternative antiviral, versus those that require only structured management strategies such as temporary medication holding, dose adjustment, or enhanced monitoring.[8,9] This distinction is central to the clinical decision at the point of prescribing. Our study addresses these gaps by anchoring the DDI classification directly to the Food and Drug Administration (FDA) Paxlovid Fact Sheet interaction table, incorporating interactions mediated by CYP3A4, cytochrome p450 2d6 (CYP2D6), and P-glycoprotein inhibition by ritonavir, and applying a two-tier classification scheme that maps directly to the distinct management pathways faced by prescribers and pharmacists.[8,9]

Building on this literature, our study provides Paxlovid-specific, nationally representative estimates anchored directly to the FDA Fact Sheet interaction table, applying transparent Tier 1 (contraindicated) and Tier 2 (avoidance/hold/dose adjustment/monitoring) classifications via ingredient-level exact matching to NHANES prescription inventory, and evaluates robustness in a sensitivity analysis restricted to interviewer-observed medications.[8] Using NHANES 2017-March 2020 pre-pandemic public-use data, we quantified the U.S. population prevalence of potential clinically significant DDIs with nirmatrelvir/ritonavir using a transparent DDI dictionary derived from the FDA Fact Sheet interaction table.[8] We report weighted national prevalence estimates overall and by age, sex, and polypharmacy, and identify the most common contraindicated medication ingredients.

Materials and Methods

Study Design and Data Source

We conducted a cross-sectional secondary analysis of the NHANES 2017-March 2020 pre-pandemic cycle. This cycle combines the 2017-2018 cycle with the partial 2019-March 2020 cycle using adjusted weights to support nationally representative inference.[13-15] NHANES is a complex, multistage probability sample of the noninstitutionalized U.S. civilian population.[15]

Study Population

Adults aged ≥18 years with valid interview weights and prescription medication questionnaire data were included. Medication exposure reflected self-reported prescription use in the prior 30 days, with container verification when available.

Exposure definition: We created a DDI dictionary based on the FDA Paxlovid Fact Sheet for Healthcare Providers table of clinically significant drug interactions.[8] Tier 1 (contraindicated) agents were defined as medications primarily metabolized by CYP3A for which elevated plasma concentrations are associated with serious or life-threatening toxicity, or strong CYP3A inducers for which co-administration would significantly reduce nirmatrelvir or ritonavir plasma concentrations and risk loss of virologic response and possible resistance.[8] Tier 2 agents were defined as medications for which co-administration requires avoidance, temporary withholding, dose adjustment, or therapeutic drug monitoring due to clinically meaningful pharmacokinetic interactions mediated by CYP3A4 inhibition and, to a lesser extent, CYP2D6 and P-glycoprotein inhibition by ritonavir.[8,9] These mechanistic tier distinctions map directly to the binary clinical decision at the point of prescribing: Tier 1 interactions require switching to an alternative antiviral regimen, whereas Tier 2 interactions may permit Paxlovid use with structured mitigation strategies. Operationally, an ingredient was assigned to Tier 1 if it appeared under the FDA Fact Sheet's contraindicated or "not recommended for co-administration" categories due to risk of serious toxicity or virologic failure; all remaining listed interactions requiring avoidance, dose adjustment, or monitoring were assigned to Tier 2. Generic ingredients were normalized and mapped to NHANES generic medication names. The final dictionary contained 149 unique ingredients (39 Tier 1 and 111 Tier 2), represented by 150 rows including headings, synonyms, and mapping variants.

Outcomes

Primary outcomes were the weighted prevalence of (1) any Tier 1 contraindicated medication, (2) any Tier 2 medication requiring avoidance/management, and (3) any clinically significant interaction (Tier 1 or Tier 2). Secondary outcomes included prevalence stratified by age group (18-49, 50-64, ≥65 years), sex, and polypharmacy (defined as ≥5 concurrent valid prescription medications), and identification of the most common Tier 1 contraindicated ingredients in the U.S. population.

Ethical Approval

This study used publicly available, de-identified NHANES data and did not constitute human subjects research under U.S. regulations.

Statistical Analysis

We followed National Center for Health Statistics (NCHS) analytic

guidance for NHANES 2017-March 2020 pre-pandemic analyses, incorporating interview weights (WTINTPRP), strata (SDMVSTRA), and primary sampling units (SDMVPSU) to produce nationally representative estimates and valid variance estimates.[13-15] Weighted prevalences and 95% confidence intervals (CIs) were estimated using Taylor series linearization. Sensitivity analyses restricted medication reporting to prescriptions observed by the interviewer (prescription medication seen variable [RXQSEEN] = 1).

Reporting Guidelines

This study was reported in accordance with the STROBE guideline.

Results

The analytic sample included 9,693 adults, representing approximately 247.9 million U.S. adults. In weighted estimates (Supplementary Table 1), 53.9% (95% CI 51.4-56.3) were aged 18-49 years, 25.7% (95% CI 24.2-27.2) were aged 50-64 years, and 20.4% (95% CI 18.2-22.6) were aged ≥65 years. Females comprised 51.8% (95% CI 50.2-53.3) and males 48.2% (95% CI 46.7-49.8). Race/ethnicity distribution was 62.2% (95% CI 57.4-66.9) non-Hispanic White, 11.5% (95% CI 8.7-14.3) non-Hispanic Black, 8.6% (95% CI 6.4-10.8) Mexican American, 7.7% (95% CI 6.3-9.2) other Hispanic, and 10.0% (95% CI 8.1-12.0) other race (including multi-racial) (Supplementary Table 1). National prevalence of potential clinically significant DDIs with nirmatrelvir/ritonavir was substantial (Table 1). Overall, 6.9% (95% CI 5.6-8.1) of adults had at least one Tier 1 contraindicated medication, 27.7% (95% CI 26.0-29.4) had at least one Tier 2 medication requiring avoidance/management, and 31.2% (95% CI 29.1-33.2) had any Tier 1 or Tier 2 medication. These correspond to approximately 17.1 million adults with Tier 1 contraindications and 77.3 million adults with any clinically significant DDI.

Prevalence increased with age. Any clinically significant DDI prevalence was 16.9% (95% CI 15.5-18.4) in adults 18-49 years, 36.3% (95% CI 33.0-39.7) in adults 50-64 years, and 62.3% (95% CI 59.1-65.4) in adults ≥65 years. Tier 1 contraindications increased from 1.6% (95% CI 1.2-2.0) (18-49 years) to 8.4% (95% CI 6.1-10.7) (50-64 years) and 18.9% (95% CI 16.0-21.8) (≥65 years); Tier 2 interactions increased from 15.8% (95% CI 14.4-17.2) to 32.4% (95% CI 29.3-35.5) and 53.3% (95% CI 49.9-56.8). By sex, any clinically significant DDI prevalence was 29.5% (95% CI 26.6-32.3) in males and 32.8% (95% CI 30.7-34.9) in females.

Table 1. Weighted prevalence of potential nirmatrelvir/ritonavir (Paxlovid) drug-drug interaction exposure

Variable	n	Weighted % (95% CI)
Any Tier 1 contraindicated medication	748	6.88 (5.63-8.13)
Any Tier 2 medication requiring avoidance /hold/dose adjustment/monitoring	2957	27.74 (26.04-29.44)
Any Tier 1 or Tier 2 medication	3304	31.18 (29.15-33.22)

Definitions: Tier 1 = contraindicated with nirmatrelvir/ritonavir; Tier 2 = requires avoidance/temporary holding, dose adjustment, or close monitoring. Tiers derived from FDA Paxlovid Fact Sheet and applied via ingredient-level exact matching.
Abbreviations: CI = Confidence Interval; FDA = Food and Drug Administration.

Polypharmacy was common: 17.1% (95% CI 15.7-18.6) of U.S. adults used ≥5 concurrent prescription medications. Among adults with polypharmacy, 86.5% (95% CI 83.6-89.4) had any clinically significant DDI, and 22.4% (95% CI 19.0-25.8) had a Tier 1 contraindication. Among adults without polypharmacy, 19.8% (95% CI 18.1-21.4) had any clinically significant DDI, and 3.7% (95% CI 2.8-4.6) had a Tier 1 contraindication (Supplementary Table 2). The most common Tier 1 contraindicated medication ingredients included simvastatin (4.27% [95% CI 3.35-5.19]); lovastatin (0.84% [95% CI 0.49-1.19]); colchicine (0.27% [95% CI 0.09-0.45]); carbamazepine (0.21% [95% CI 0.02-0.41]); lurasidone (0.21% [95% CI 0.05-0.37]) (Supplementary Table 3). In sensitivity analyses restricted to prescriptions observed by the interviewer (RXQSEEN = 1), prevalence estimates were modestly lower but remained high: Tier 1 6.1% (95% CI 4.8-7.3), Tier 2 24.9% (95% CI 23.3-26.4), and any DDI 28.0% (95% CI 26.1-30.0) (Supplementary Table 4).

Discussion

In this nationally representative analysis, nearly one-third of U.S. adults used at least one medication with potential clinically significant interaction with nirmatrelvir/ritonavir as listed in FDA labeling, and approximately 7% used contraindicated (Tier 1) medications that may preclude use without switching therapies.[8] The interaction burden was strongly age-graded and concentrated among adults with polypharmacy, highlighting that patients at the highest baseline risk for severe COVID-19 also face the greatest DDI-related prescribing complexity. These findings are concordant with prior U.S. population-level estimates of ritonavir-related interaction risk and with studies focused on older adults showing high prevalence of interacting medications.[10,11] Although many interactions can be managed safely (e.g., time-limited holding of selected lipid-lowering agents, dose adjustment, or monitoring), feasibility depends on rapid medication reconciliation, clear protocols, and timely access to clinical pharmacy support.[7,9,12]

Comparison with prior NHANES-based work: Our estimates extend and differ from the prior NHANES-based DDI analysis by Igho-Osagie et al. in three important ways.[11] First, our DDI dictionary was anchored to the FDA Paxlovid Fact Sheet, reflecting the specific interaction profile of nirmatrelvir/ritonavir, including interactions mediated by CYP2D6 and P-glycoprotein inhibition in addition to CYP3A4, rather than a broader CYP3A4-only framework applied to ritonavir-containing COVID-19 therapy generically.[11] Second, our two-tier classification operationalizes the clinically critical distinction between contraindicated agents (which preclude Paxlovid use without therapy switching) and manageable agents (which may permit Paxlovid use with time-limited mitigation), a distinction that is central to real-world prescribing decisions but absent from prior NHANES-based estimates. Third, by providing Tier-stratified national prevalence estimates, our study enables direct quantification of the proportion of U.S. adults who face absolute prescribing barriers versus those for whom DDI-informed management protocols could expand access. This is a policy-relevant distinction not previously derivable from population-level data. In brief, this study estimates the national prevalence of absolute versus manageable Paxlovid prescribing barriers, not merely overall ritonavir-related DDI burden.

Clinical implications: Our results support embedding DDI screening as a default, workflow-based step in outpatient antiviral prescribing and suggest the need for such integration. Despite Paxlovid's proven real-world effectiveness, with large-scale target trial emulation estimating reductions in hospitalization risk of approximately 39% and in mortality of approximately 61%, antiviral prescribing remains markedly suboptimal in the highest-risk populations.[16] A 2026 MMWR analysis found that fewer than one-quarter of eligible adults aged ≥65 years received a COVID-19 antiviral during several recent seasonal periods, with concerns about drug interactions cited as a primary barrier.[17] A parallel study similarly documented that lack of prescriber familiarity with Paxlovid's interaction profile contributes to underutilization, specifically among older adults, the very population for whom antiviral benefit is greatest.[18] The convergence of our population-level prevalence data with real-world pharmacovigilance findings is particularly notable: simvastatin was the most prevalent Tier 1 agent in our analysis (4.27%), consistent with pharmacovigilance data identifying simvastatin as the most frequently reported drug associated with potential DDI adverse events in nirmatrelvir/ritonavir-exposed patients

globally (Supplementary Table 3).[19] This alignment between population-level risk estimates and observed real-world harm events supports the clinical relevance, and not merely descriptive value of our prevalence findings. Furthermore, among adults with polypharmacy, where our estimates show 86.5% carry any DDI and 22.4% a Tier 1 contraindication, proactive deprescribing strategies may represent an underutilized tool for expanding treatment eligibility (Supplementary Table 2). The COVID-SAFER analysis found that 68% of hospitalized older adults with polypharmacy had a nirmatrelvir-ritonavir DDI and that 21% were taking at least one potentially inappropriate medication, many of which required complex deprescribing strategies rather than simple holding.[20] Our nationally representative estimates suggest this burden extends across the broader outpatient population, supporting the need for anticipatory medication optimization integrated into routine chronic disease management. Standardized medication reconciliation and patient counseling may benefit from integration with decision support and pharmacist escalation pathways for common interaction classes. Systems should also maintain readiness to deploy alternate therapies when contraindications or management complexity would delay treatment beyond the effective window.[7-9,12]

Implications for guidelines and health practice: Current clinical guidance prioritizes nirmatrelvir/ritonavir for many high-risk outpatients while acknowledging that DDIs may necessitate alternate antivirals.[11] By quantifying the national scale of potential clinically significant DDIs, our findings support guideline-concordant investment in medication management infrastructure and targeted decision support, particularly for older adults and those with polypharmacy.

Strengths include the use of nationally representative NHANES data, complex-sampling variance estimation, and a transparent, FDA-label-anchored DDI operationalization. Limitations include reliance on pre-pandemic medication patterns; incomplete capture of nonprescription agents; and inability to incorporate dose, renal function-based adjustments, timing, or clinician-supervised holding strategies. Consequently, these estimates should be interpreted as potential interaction prevalence requiring clinical adjudication at the point of care.

Limitations

This study has several limitations. First, medication exposure was based on NHANES self-reported prescription use in the prior 30 days, which may incompletely capture true medication use despite interviewer verification when available. Second, NHANES does not fully capture over-the-counter, herbal, recreational, inpatient, or procedure-administered medications, and we could not account for dose, treatment duration, renal function, timing of coadministration, or clinician-directed temporary holding strategies; therefore, these findings represent potential rather than adjudicated contraindications. Third, because the analysis used 2017-March 2020 pre-pandemic data, prescribing patterns may not fully reflect the therapeutic landscape during later phases of COVID-19 antiviral use. These limitations likely result in conservative estimates and support the interpretation of our findings as population-level prescribing complexity rather than definitive patient-level ineligibility.

Conclusion

Approximately 31.2% (95% CI 29.1-33.2) of U.S. adults, about 77.3 million people, use medications with potential clinically significant interactions with nirmatrelvir/ritonavir, and 6.9% (95% CI 5.6-8.1) have contraindicated medications. These results underscore the need for rapid, standardized DDI assessment and management to maximize equitable access to guideline-recommended outpatient antiviral therapy while minimizing preventable adverse drug events.

Declarations

Ethics Declarations

Ethics approval and consent to participate: This study used de-identified, publicly available data from the National Health and Nutrition Examination Survey (NHANES) 2017-March 2020 pre-pandemic public-use datasets provided by the National Center for Health Statistics, Centers for Disease Control and Prevention. As no human participants were directly involved and all data were fully de-identified and publicly accessible, ethics committee approval and informed consent were not required.

Animal and Human Rights Statement

This study did not involve any human participants or animal subjects.

Informed Consent

Not applicable.

Data Availability

The datasets used and/or analyzed during the current study are not publicly available due to patient privacy reasons but are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Author Contributions (CRediT Taxonomy)

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Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content, including study design, data collection, analysis and interpretation, writing, and some of the main line, or all of the preparation and scientific review of the contents, and approval of the final version of the article.

Abbreviations

CI: confidence interval
COVID-19: Coronavirus disease 2019
CYP3A: Cytochrome p450 3a
CYP3A4: Cytochrome p450 3a4
CYP2D6: Cytochrome p450 2d6
DDI: Drug-drug interaction
FDA: Food and drug administration
NHANES: National health and nutrition examination survey
NCHS: National center for health statistics
RXQSEEN: Prescription medication seen variable
SDMVPSU: Masked variance pseudo-primary sampling unit
SDMVSTRA: Masked variance pseudo-stratum
STROBE: Strengthening the reporting of observational studies in epidemiology
WTINTPRP: Interview sample weight variable

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Electromagnetic fields in nucleic acids: a new perspective on their potential role in epigenetics and evolution

Eurasian Clinical and Analytical Medicine Review

Electromagnetic genomic interactions

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Abstract

Electromagnetic fields (EMFs), either in physical or biological systems, can be found in cells via charge movement, membrane potentials, and molecular dipoles. Although their influences on processes like proliferation and signaling are being studied more frequently, interactions with nucleic acids are less well-defined. According to this hypothesis, the DNA's natural electromagnetic properties might act on transcriptional regulation through dipole interactions in base pairs. For example, the ordered hydrogen bonds from A,T,G, and C in the DNA helix could form localized electromagnetic patterns that may control conformational dynamics or transcription mechanisms. Such effects could provide an additional layer of regulation, working in synergy with classical epigenetic signals. To this end, here we present a conceptual framework and experimental design to test whether EMF exposure in a controlled manner can modulate transcriptional efficiency or protein expression independent of DNA sequence. If they prove to be accurate, such discoveries could offer important new information on the regulation of gene activity, epigenetic responses to environmental stress, and adaptation during the evolution of species.

Keywords

electromagnetic field, biomagnetism, DNA transcription, evolution, epigenetics

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Introduction

Carbon is the building block of life. The Earth is full of carbon-based life forms because compounds of carbon are abundant on it, and carbon-containing molecules, including nucleic acids, have extraordinary structural and chemical versatility. A carbon atom can associate with four different atoms at the same time. Also, enzymes easily manipulate carbon molecules due to their light weight and relatively small size. These superiorities make carbon an ideal element for forming deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) chains, which are the basis of life.[1]

Nucleic acids contain 5 carbons of sugar (pentose), phosphate, and base. The nitrogenous organic base is attached to a pentose sugar by a glycosidic bond, while the phosphate is connected by an ester bond. This formation is called a nucleotide. Nucleotides are attached by phosphodiester bonds to form a chain. The bond between the two complementary chains occurs by the coupling of the bases. This coupling occurs when the appropriate bases are joined by mutual weak hydrogen bonds (H+). As a result, nucleotides joined by phosphodiester bonds and stabilized by base-pair hydrogen bonds form DNA and RNA. The characteristic double-helical structure of DNA, necessary for genetic storage and accurate transcription, is formed by the spatial arrangement of these bonds.

Genetic information is transmitted from the template DNA sequence by the catalytic action of the enzyme RNA polymerase through the synthesis of messenger RNA (mRNA) in the nucleus. This process is called transcription. DNA sequence, chromatin structure, histone modifications, and noncoding RNAs delicately regulate transcription. These regulatory mechanisms in gene transcription, collectively, can create order out of chaos within cells, thus enabling cells to translate environmental conditions into gene expression.

Electromagnetic Field (EMFs) can be defined as a force field with electrical and magnetic components that is formed by the rotation of electrons in atoms around the nucleus and around themselves. In biological systems, EMFs arising naturally from molecular charges, ion movement, and electrical currents in tissues create biomagnetism.[2,3] Indeed, considering that every cell in the human body has its own electrical circuit, our body can actually be compared to a huge electromagnetic device. In this context, it would be reasonable to think that biomagnetic fields produced internally by biological processes in our bodies, or artificial EMFs produced by modern technology we encounter in the environment, are physical factors that can influence gene regulation.

Research conducted together with DNA studies and applied physics offers us new ideas into the regulation of gene transcription. Although it is an increasingly popular field of research to evaluate the effects of EMFs on morphology, survival capacity, membrane permeability and proliferation rate of cell, cell cycle progression (division-mitosis or meiosis), mitochondrial activity, oxidative stress, embryonic development, cell signal transduction, biomolecules, and regulatory proteins.[4-15] the interactions between biomagnetic fields and genetic information processing have not yet been sufficiently explored. This hypothesis suggests a possible link between the electromagnetic microenvironment of DNA and the regulation of transcription.

Materials and Methods

This study was conducted in the form of a narrative literature review. Relevant publications were identified via a systematic review of literature by manual search using the PubMed and Google Scholar databases. Search strategy: The following keywords were searched in combinations: Electromagnetic Field, biomagnetism, DNA transcription, evolution, and epigenetics.

Filtering through the results through a series of various keywords that implied studies pertaining to Electromagnetic Field, biomagnetism (more specifically as it pertains to DNA transcriptomics and evolution), and epigenetics. Original research and relevant review articles were included, while studies not directly related to the topic or not written in English were excluded.

Titles and abstracts were screened, followed by full texts to identify potentially applicable studies. Given the narrative nature of this review, a standard systematic review framework (for example, PRISMA) or quality assessment tool was not employed.

Eligible studies were subject to data extraction and descriptive synthesis. The resulting hits were thematically organized for a summary of the current literature covering biomagnetism and electromagnetic fields during DNA transcription.

Ethical Approval

This study did not require ethical approval as it is a narrative review and hypothesis-based study that did not involve human participants, patient data, or animal subjects.

Reporting Guidelines

No specific reporting guideline was followed, as this study is a narrative review and hypothesis-based paper.

Results

Results Hypothesis

The regular sequence of dipole interactions within DNA base pairs creates extremely small but structured electromagnetic fields because hydrogen bonds generate very small electrostatic forces. However, the repetitive and helical organization of these interactions, which can number in the millions, can create local electromagnetic patterns within the DNA molecule. Transcription processes can be affected by these intrinsic electromagnetic patterns that could theoretically regulate: the conformational dynamics of DNA (e.g., unwinding, bending, groove width), the interaction environment of RNA polymerase, the binding of transcription factors, and local chromatin organization. If this is true, these intrinsic patterns can be altered by exposure to external electromagnetic fields without changing the genetic sequence, in which case transcription efficiency can be affected, protein expression can be altered, and epigenetic-like effects can occur. This type of EMF-sensitive alteration might potentially play a role in both epigenetic and evolutionary processes. This does not replace previously recognized biochemical epigenetic pathways but provides an alternative mechanism by which environmental physical forces can modulate gene expression. We note that this hypothesis is speculative and should be tested stringently.

Theoretical Rationale

Electromagnetic Properties of DNA: DNA is not a data storage in the classic ferromagnetic sense; however, it has: electric dipoles (hydrogen bonds), charge distribution along the backbone, and can interact with an external field through polarization current.[16] The helical pattern at the nanometer-scale could enable emergent electromagnetic phenomena, whose role in biology is however, unknown. Single-stranded nucleic acids, such as RNA, are more structurally polymorphic and therefore have additional flexibility for electromagnetic interactions.

EMFs as Environmental Signals: Epigenetic mechanisms translate external and internal stimuli–chemicals, nutrients, and temperature -- into changes in chromatin properties and gene expression.[17,18] However, if EMFs affect transcription independent of the DNA sequence, they may serve as an alternative environmental modulator.

Evolutionary Considerations: Natural EMFs exhibit geographical

fluctuation, and this depends on Earth's magnetic field strength as well as local anomalies.[19] Even though highly speculative, if exposure to EMFs has the potential to delicately influence patterns of gene expression over generations, they could be involved in local adaptation or phenotypic diversity. This may be worth exploring, but it should be considered carefully since established genetic and selection mechanisms are still the main explanation for regional genetic characteristics.

Proposed Experimental Approach

There is currently no experimental data in the literature on this subject. However, an experiment like the following could be suggested to investigate whether electromagnetic fields affect DNA transcription or base pairing.

EMF Exposure System: In this project, first of all, a computer-aided circuit arrangement consisting of a cryostat temperature-controlled chamber, a closed-circuit cooling sysem, and a CO_2 flow control system will be established to provide a controlled EMF exposure environment at varying sizes and time intervals within a constant temperature environment. Also, a magnetic field generator capable of producing static fields of up to 1.2 Tesla to be applied to biological samples, optional low-frequency alternating current (AC) fields for comparison, a helium compressor for low-temperature testing, and a molecular vacuum pump system for vacuuming the cryostat containing the biological sample will be installed. With this system, the EMF intensity, frequency, and exposure time can be systematically varied.

DNA-Level Assays: In this step, it will be investigated whether the expression of this gene product changes in different EMFs by cloning a well-characterized eukaryotic gene (e.g., green fluorescent protein [GFP] or luciferase) into a prokaryotic expression vector. The purified DNA will be denatured and renatured under controlled EMF exposure, and tested by DNA Sequencing to determine whether EMFs alter base pairing fidelity (no sequence-level changes are expected; so, this serves as a control). Finally, the Comet Assay will be used to detect breaks or damage in DNA strands.

Transcription and Protein Expression: Subsequently, the EMF-exposed expression vector carrying the "Eukaryotic Gene" will be transferred to a cell line that does not naturally express the gene, thus achieving the transformation. Then, gene expression analysis will be performed through mRNA levels measured by reverse transcription quantitative polymerase chain reaction (RT-qPCR) under different EMF conditions. Protein characterization will be completed by determining protein abundance using Western blot or fluorescence methods, and by examining structural accuracy using mass spectrometry to detect amino acid misincorporation. In the final stage, the functional test will be performed by determining the activity of the expressed protein (e.g., the function of the luminescence enzyme).

Expected Outcomes: Possible findings can be summarized as follows: i) No effect may occur: EMFs do not affect transcription or protein expression (null hypothesis); ii) Modulation may occur without mutation: EMFs alter transcription levels or protein yield without changing the DNA sequence; this supports an epigenetic-like effect; iii) Sequence or structural changes may occur: this means unexpected but informative changes in accuracy.

Discussion

DNA is an amazing molecule with an extraordinary density of potential magnetic storage. Genetic information storage in DNA also requires an encoding and decoding scheme, like the magnetic hard drive in computers. The structure of DNA is a double helix, which is based on four nucleotide bases: adenine (A), cytosine (C), guanine (G), and thymine (T). The structure of DNA, based on these four nucleotide bases, provides more storage space than the binary system in magnetic hard disks. Data is stored volumetrically in a DNA molecule. Interestingly, DNA-like helical structures in a magnetic field tend to form large-scale structures from small-scale ones.[20] This allows DNA to store more information as opposed to other media that store data linearly. In addition to the conduction current, a polarization current can also occur in the DNA molecule, which can answer the question of whether single-stranded DNA molecules have magnetic properties.16 Moreover, the fact that single-stranded DNA molecules, such as RNAs, have a wider variety of 3-dimensional structures seems to support this view. Also, storing genetic information in DNA does not require any energy or maintenance, so DNA in fossils can be preserved for many years.

EMF is a physical phenomenon that cannot be directly seen or felt easily, but its results can be tested. The electromagnetic field, a vector magnitude, is generated internally by moving electric charges, by time-varying electric fields, or by fundamental particles. So, it is defined by direction and intensity at any point. In the special theory of relativity, electric and magnetic fields are two related properties of an object. In quantum physics, electromagnetic interactions occur as a result of photon exchange. The generation, transmission, and distribution system of electrical energy plays an important role in our lives. Furthermore, EMF is used in the transport and storage of information.

Epigenetics is the study of heritable but reversible changes in gene function caused by environmental factors without requiring a change in the DNA sequence.[21] In other words, epigenetics describes changes in phenotype without a change in genotype based on how cells read genes. Gene expression can be controlled by silencing of DNA (by means of DNA methylation, histone modification, non-coding RNAs, et.) in many types of epigenetic inheritance.[17,22-24] Both the environment and individual lifestyle can affect the way genes work, resulting in epigenetic change. These epigenetic changes can continue throughout the life of the cell through cell divisions and may also persist for multiple generations.[18] Thus, transgenerational epigenetic inheritance may affect phenotypic plasticity and adaptation. Furthermore, epigenetic mechanisms may also help drive genome evolution.

At this point, if it is assumed that external EMFs regulate transcription efficiency or protein expression without altering the DNA sequence, it may be reasonable to argue that the electromagnetic microenvironment could play a significant role in contributing to gene regulation by creating an additional physical layer influencing cellular behavior, even if it cannot replace established epigenetic mechanisms.

Finally, potential outcomes of this hypothesis may be: novel insights into how living entities experience the surrounding EMFs, application of this knowledge to human biology (e.g., effects of EMF on immune system or in cancer therapy), alternative view on the long-term role of physical fields in life development (like a new and easier way to explain the effect of environmental factors on evolution and phenotypic plasticity). However, we would like to stress that this speculation has not been confirmed by experiments until now. These hydrogen bond-derived EMFs are extremely weak, and ensuring biocompatibility will require rigorous reproducibility and careful controls.

Limitations

This study has several key limitations that should be noted. To start with, although the proposed model is very interesting and thought-provoking, at this point it remains speculative without experimental corroboration. Although the suggested impact of EMF on DNA transcription based on inherent electromagnetic signals is theoretical, it does have a sound physical basis. Second, the physical strength of electromagnetic forces created by hydrogen bonds and molecular dipoles inside DNA is very low. It is unclear whether such weak fields can impact biologically

functional effects in dynamically noisy intracellular environments, where thermal fluctuations and biochemical interactions prevail. Third, the experimental design proposed is conceptually sound but practically very difficult. Controlling EMF exposure with precision, separating it from confounding environmental factors, and ensuring replication across biological systems could be challenging. Moreover, separating real electromagnetic effects from secondary stress responses triggered in the cells or indirect biochemical pathways will necessitate stringent controls. Fourth, extrapolating possible EMF effects to epigenetic control of genes and evolutionary processes must remain wholly speculative. The established mechanisms of genetic variation and natural selection remain the key drivers of evolutionary change, and any potential contribution of EMFs needs to be viewed with caution unless bolstered by robust empirical data.

Ultimately, this study fails to account for intercell-type, organism, or environmental variability that may affect sensitivity toward electromagnetic exposure. Standardized exposure parameters in addition to different biological models, will help generalize our findings, in future research.

Conclusion

We introduce a speculative, but experimentally testable model suggesting that endogenous and exogenous electromagnetic fields could have an effect on DNA transcription by acting directly upon the electromagnetic microenvironment of nucleic acids. We describe an experimental paradigm for detecting EMF-mediated effects at the DNA pairing, transcriptional, translational, and post-translational levels of proteins, which represents an excellent template platform for interdisciplinary research fusing physics with molecular biology and epigenetics.

If confirmed, this idea could yield novel insight into gene regulation and could help to explain both environmentally responsive phenotypes as well as more gradual evolution.

Declarations

Ethics Declarations

This study did not require ethical approval as it is a narrative review and hypothesis-based study that did not involve human participants, patient data, or animal subjects.

Animal and Human Rights Statement

This study did not involve any human participants or animal subjects.

Informed Consent

Not applicable.

Data Availability

The datasets used and/or analyzed during the current study are not publicly available due to patient privacy reasons but are available from the corresponding author on reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest.

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Author Contributions

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Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content, including study design, data collection, analysis and interpretation, writing, and some of the main line, or all of the preparation and scientific review of the contents, and approval of the final version of the article.

Abbreviations

AC: Alternating current
CO_2: Carbon dioxide
DNA: Deoxyribonucleic acid
EMF: Electromagnetic field
GFP: Green fluorescent protein
H^+: Hydrogen ion
mRNA: Messenger ribonucleic acid
RNA: Ribonucleic acid
RT-qPCR: Reverse transcription quantitative polymerase chain reaction

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